Measurement of open-charm hadrons in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV by the STAR experiment

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PHYSICS MOTIVATION

One of the main goals of the heavy-ion program at the STAR experiment is to study properties of the Quark-Gluon Plasma (QGP). Charm quarks are an excellent probe of the QGP as they are produced at very early stages of ultra-relativistic heavy-ion collisions and therefore experience the whole evolution of the hot and dense medium. STAR is able to study production of charm quarks through a precise topological reconstruction of open-charm hadron decays utilizing the Heavy Flavor Tracker (HFT) [1].

Various measurements are used to study interactions of charm quarks with the QGP. In these proceedings, we present a selection of recent results on open-charm hadron production from the STAR experiment. In particular, we discuss the nuclear modification factors ($R_{\rm AA}$) of $\rm D^{\pm}$ and $\rm D^0$ mesons which give access to the charm quark energy loss in the QGP. We show the $\Lambda_{\rm c}^{\pm}/\rm D^0$ and $\rm D_s/D^0$ yield ratios which help us better understand the charm quark hadronization process in heavy-ion collisions. In addition, we present the rapidity-odd directed flow of $\rm D^0$ mesons, which can be used to probe the initial tilt of the QGP bulk and the effects of the early-time magnetic field.

RESULTS

Figure 1 shows the $R_{\rm AA}$ of $\rm D^0$ [2] and $\rm D^{\pm}$ mesons as a function of transverse momentum ($p_{\rm T}$) in 0-10% central Au+Au collisions. Both open-charm mesons show a significant suppression at high $p_{\rm T}$ which suggests strong interactions of the charm quarks with the QGP. The $R_{\rm AA}$ evolution in low to intermediate $p_{\rm T}$ region suggests a large collective flow of charm quarks [2].

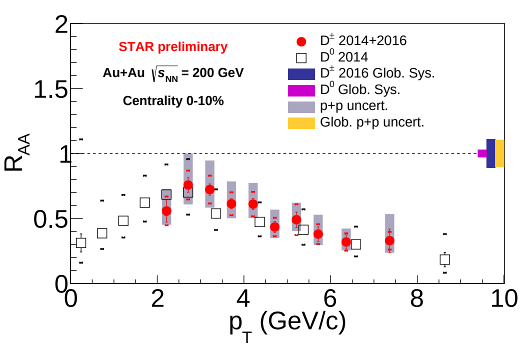

Fig. 1. $R_{\rm AA}$ of $\rm D^0$ [2] and $\rm D^{\pm}$ mesons as a function of $p_{\rm T}$ in 0-10% central Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV.

The presence of the QGP may also influence the charm quark hadronization. In order to study that, STAR has measured the $\Lambda_{\rm c}^{\pm}/\rm D^0$ yield ratio as a function of number of participants ($N_{\rm part}$) [3] as shown in Fig. 2. In central collisions, the ratio shows an enhancement with respect to PYTHIA 8.2 p+p calculations (Monash tune [4]) with and without color reconnection (CR) [5]. The centrality dependence follows a similar trend as baryon to meson ratio of light flavor hadrons [6, 7]. The data are reasonably reproduced by the Catania model incorporating coalescence and fragmentation hadronization of the charm quarks [8].

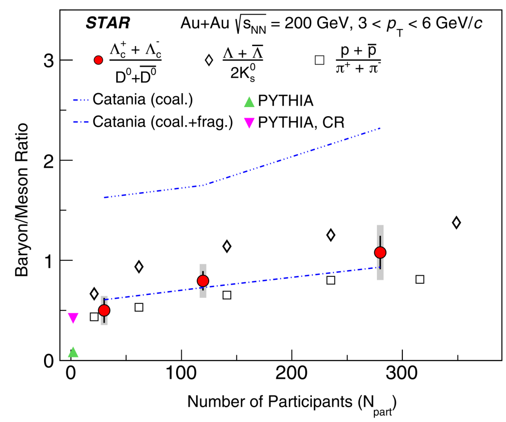

Fig. 2. $\Lambda_{\rm c}^{\pm}/\rm D^0$ yield ratio as a function of number of participants $N_{\rm part}$. The open-charm hadron data are compared to measurements of light flavor hadrons [6, 7], PYTHIA calculation and the Catania model incorporating coalescence and fragmentation hadronization of the charm quarks [8]. Taken from Ref. [3].

To get more detailed information about hadronization of charm quarks, STAR has also measured the $\rm D_s/D^0$ yield ratio, as shown in Fig. 3. The ratio is enhanced with respect to a PYTHIA 8.2 calculation, suggesting enhanced $\rm D_s$ production in Au+Au collisions with respect to p+p collisions. The data are qualitatively described by various models incorporating coalescence and fragmentation hadronization [8, 9, 10].

Theoretical calculations predict that the charm quarks could also be used to probe the initial tilt of the QGP bulk and the electromagnetic (EM) field induced by the passing spectators [11]. The former leads to a large negative slope of the directed flow versus rapidity (dv_1/dy) of open-charm mesons, and the latter to a negative slope for $\rm D^0$ and a positive slope for $\overline{\rm D^0}$. When combined, the slope is predicted to be negative for both $\rm D^0$ and $\overline{\rm D^0}$ but larger for $\rm D^0$ than for $\overline{\rm D^0}$ in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. The STAR results on $\rm D^0$ and $\overline{\rm D^0}$ v_1 are shown in Fig. 4. The current precision of the measurement is not sufficient to

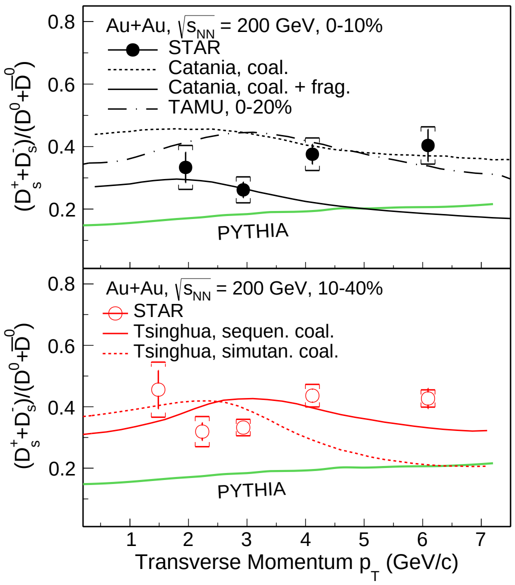

Fig. 3. D_s/D^0 yield ratio as a function of p_T. The data are compared to various models incorporating coalescence and fragmentation hadronization of charm quarks [8, 9, 10] and PYTHIA p+p calculations.

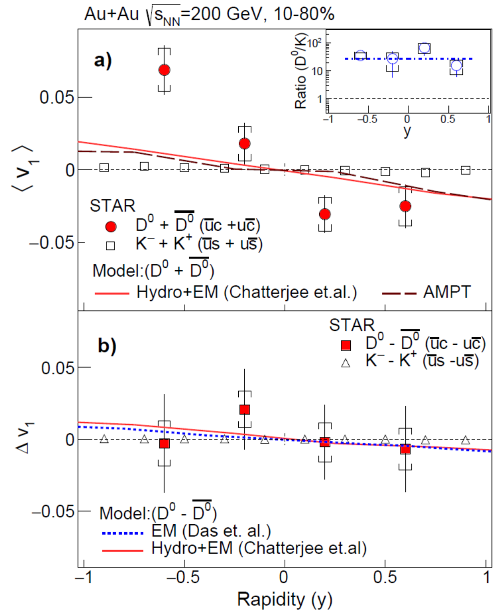

Fig. 4. **(a)** Directed flow of D^0 and $\overline{D^0}$ mesons at $p_T > 1.5$ GeV/c as a function of rapidity in 10-80% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV, compared to calculations of a hydrodynamic model with an initial EM field [13] and the AMPT model [14]. (b) Difference in v_1 between D^0 and $\overline{D^0}$ compared to a model prediction with only the initial EM field [13] and one that combines EM effects with hydrodynamics [11]. The D^0 data are compared to measurement of charged kaons [15]. Taken from Ref. [12].

conclude on the EM induced splitting, but the dv_1/dy slope is indeed negative and significantly larger than that of light-flavor mesons, as discussed in Ref. [12].

CONCLUSIONS

The STAR experiment has extensively studied the production of open-charm hadrons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV through a precise topological reconstruction of their hadronic decays, utilizing the HFT. The latest results show that the D^0 and $D^{\pm}$ mesons are suppressed in central Au+Au collisions, suggesting a substantial energy loss of the charm quarks in the QGP. The QGP seems to influence the charm quark hadronization. The STAR results on the $\Lambda_c^{\pm}/D^0$ and D_s/D^0 yield ratios are in qualitative agreement with theoretical models incorporating coalescence and fragmentation hadronization of charm quarks. The measured D^0 dv_1/dy slope is qualitatively consistent with hydrodynamical model calculations with tilted QGP bulk [11].

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